Neuromuscular Rehabilitation via Telebiofeedback as a Portal for Home Care

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Background

Stroke is the third leading cause of death in the United States and it affects 570,000 people per year. The care costs for stroke victims are estimated to be in excess of $30 billion annually [1-3]. Rehabilitation is a key component of the stroke recovery process, but inpatient rehabilitation stays are decreasing in length, leaving stroke victims with multiple outpatient rehabilitation needs. These needs can be addressed by evaluating the feasibility of telemedical rehabilitation.

There are approximately 30 Physical Medicine and Rehabilitation specialists in the United States Army. These specialists are located at the major medical centers and two major troop posts. As the need for rehabilitation of military personnel exists beyond these geographic locations, a telemedical model of rehabilitation may provide a feasible option of alternative healthcare delivery.

The goal of this pilot study was to determine the feasibility of using telemedicine technology to provide biofeedback facilitated rehabilitation therapy to patients with hemiplegic gait. A Technology to Induce Movement (TIM) computer system that utilized surface electrodes (sEMG), was attached to subjects' specific muscle groups and muscleactivity drove cursor movements on a computer. Sessions were directed in real time by a "remote" physical therapist who encouraged subjects to perform specific therapeutic motor control exercises.

Therapist and subject satisfaction questionnaires showed high rates of satisfaction with the TIM-type system via telemedicine. Subjects also showed improvements in the Berg Balance Test, seated toe tapping, timed ascent/descent of stairs and angles of ankle/knee flexion at mid swing of the gait cycle .

Methods

- Pilot study, prospective, self-controlled clinical trial with serial measures
- Six hemiplegic subjects enrolled
- SEMG TIM type system used
- 45 minute telebiofeedback sessions, twice a week for six weeks
- Electrodes placed on muscles that control dorsiflexion and plantar flexion of hemiplegic ankle
- Subjects performed specific motor control exercises that interfaced with a video game on a computer screen
- Functional gait and motor ability assessment data collected by physiatrist, physical therapist and gait lab technician, pre, six weeks and two months post telebiofeedback.
- Subject data from the Berg Balance Test, seated toe tapping, timed ascent/descent of stairs and ankle and knee flexion was analyzed.
- System satisfaction questionnaires presented to subjects and treating therapist at end of six week treatment.

Materials

Gait Laboratory

Digital Camera | Reflective Markers | Forceplate

Hardware

1. **Two Computers**: (800Mhz processor, 128 MB RAM Memory, 200 MB hard drive, 16 MB graphic card and 15" Monitor 1024 x 768 BPI).
2. **Two Keyboards**
3. **One EMG Amplifier**
4. **Two portable video cameras** (Quick Cam Pro 300, Logitech Corp., Fremont, CA)
5. **Two Microphones**
6. **Two sets of headphones**
7. **Two sets of speakers**

Software

1. **PC Anywhere, Version 10.5** (Symantec Corp. Cupertino, CA).
2. **Windows Net Meeting 2000** (Microsoft Corp. Redmond, WA).
3. **MotoVate System Kit** (Nicolet Biomedical, Madison, WI).

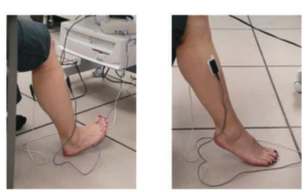
Telerehabilitation Model

(Figure by Yanko Michev)

The patient, with the help of a technical assistant is "remote" from the physical therapist evaluating and supervising the session.

Video/audio broadcast of therapist "remote" from patient.

Movements Activated by Biofeedback



Dorsiflexion | Plantar Flexion

Results

Demographic Data

Age	Gender	Diagnosis	Onset of Injury	Side of Hemiplegia
62 *	F	RT MCA Infarct	4/94	Left
75	M	LT MCA Infarct	6/78	Right
27	F	RT MCA Infarct	1/02	Left
66	M	LT MCA Infarct	12/01	Right
48	F	RT MCA Infarct	11/97	Left
58	M	RT Caudate Infarct	2/01	Left

* Subject's clinical data was not analyzed and included in the sample, as she was physically unable to perform the biofeedback technique with the muscles of dorsiflexion/plantar flexion due to stroke severity. Alternatively, her hamstrings and quadricep muscles were tested.

Clinical (n=5)

Parameter	Mean (Range)		
	Initial Evaluation	/6wks post/ 2months post	
1. Berg Balance Test (score)	49.6 (38-56)	52 (43-56)	51.2 (46-56)
2. Seated Toe Tapping (#/min)	25.2 (0-58)	31.2 (0-62)	38 (21-59)
3. Ascending 3 stairs (seconds)	5.1 (2-12)	4.3 (2-9)	4.1 (2-8)
4. Descending 3 stairs (seconds)	6.3 (2-17)	5.2 (2-13)	5.2 (2-14)

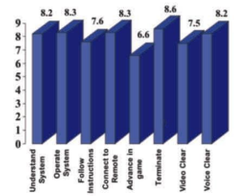
Parameter	Average Change	
	Baseline-6 wks	Baseline-2 months
1. Berg Balance Test	+2.4	+1.6
2. Seated Toe Tapping	+6	+12.8
3. Ascending 3 stairs	+0.8	+1
4. Descending 3 stairs	+1.1	+1.1

Gait Laboratory

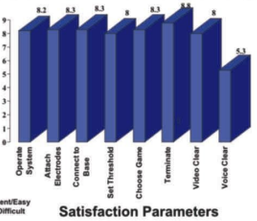
Subject	Change in Mid Swing in Angles					
	Ankle Dorsiflexion*			Knee Flexion		
	Pre	/ 6week / 2month		Pre	/ 6week / 2month	
#1	-7.8°	+2.2°	+1.2°	+41.1°	+48.2°	+49.8°
#2	-3.2°	+1.6°	+0.8°	+22.4°	+24°	+29°
#3	-2.4°	+4.4°	+4.8°	+20.3°	+32.1°	+32°
#4	+5.4°	+4.7°	+2.8°	+24.8°	+20.8°	+24.2°
#5	-11°	-13°	-12.4°	+13.4°	+11.5°	+10 °

* Ankle at neutral is 0 degrees; negative signifies degrees below neutral, i.e. plantar flexion; positive signifies dorsiflexion above neutral.
(Positive gains in red)

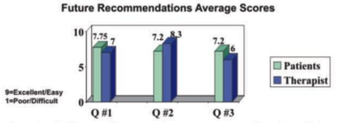
Patient Satisfaction Questionnaire (n=6) Average Scores



Therapist Satisfaction Questionnaire Average Scores



Future Recommendations Average Scores



Question #1: How would you rate the system compared to other rehab modalities?

Question #2: Would you recommend the system to other patients/therapists?

Question #3: Would you recommend the system via telemedicine?

Technology Assessment Results

Initial Setup:
- Two PC's connected via T1 line, linking subject with "remote" therapist
- Commercially available software linking interactive biofeedback software, audio and video to achieve the video teleconference

Shortfalls:
- Audio, video and software transmission lag time variations due to traffic on T1 line and hardware issues
- Lag in biofeedback transmission=lag in effectiveness of rehabilitation intervention

Solutions implemented:
- Video cards upgraded to improve visual resolution
- Microphones/headphones upgraded to improve sound quality
- Base to remote location converted from T1 universal line to direct connection to decrease lag time due to traffic

Discusion

Two of the five subjects achieved perfect scores on the Berg Balance Test at baseline, and yet they demonstrated notable improvements in gait laboratory parameters over time, suggesting a much higher sensitivity for identifying improvements with gait laboratory technology.

Clinically, hemiplegic patients do not always achieve full toe clearance of the floor during the swing phase of gait. The results of this study suggest that there may be a minimal threshold of voluntary ankle and knee flexion during swing that is required for biofeedback to be effective. Of the five subjects, the two most severely affected individuals demonstrated no gains in clearance as per gait laboratory analysis. Further studies are needed to identify this threshold so as to better identify which patients are more likely to benefit from biofeedback training.

Conclusion

Clinical:
- Further studies with a larger sample size and non telemedical biofeedback control group may help identify differences in biofeedback transmission quality with and without telemedicine.
- Selection of functional outcome measures that provide for optimal capture of functional improvements will help identify patients who would benefit most from this technology.

Technological:
- Neuromuscular biofeedback via telemedicine may be a feasible means of health care delivery in the controlled pilot study population.
- In order to provide this health care technology to larger a population beyond a "simulated" environment, advancements and upgrades in technology would be necessary.
- Expansion to a multi-site project would identify the feasibility of telebiofeedback in a true physical and technical "distance" scenario.
- A larger scale study would warrant a comprehensive cost/benefit analysis.

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